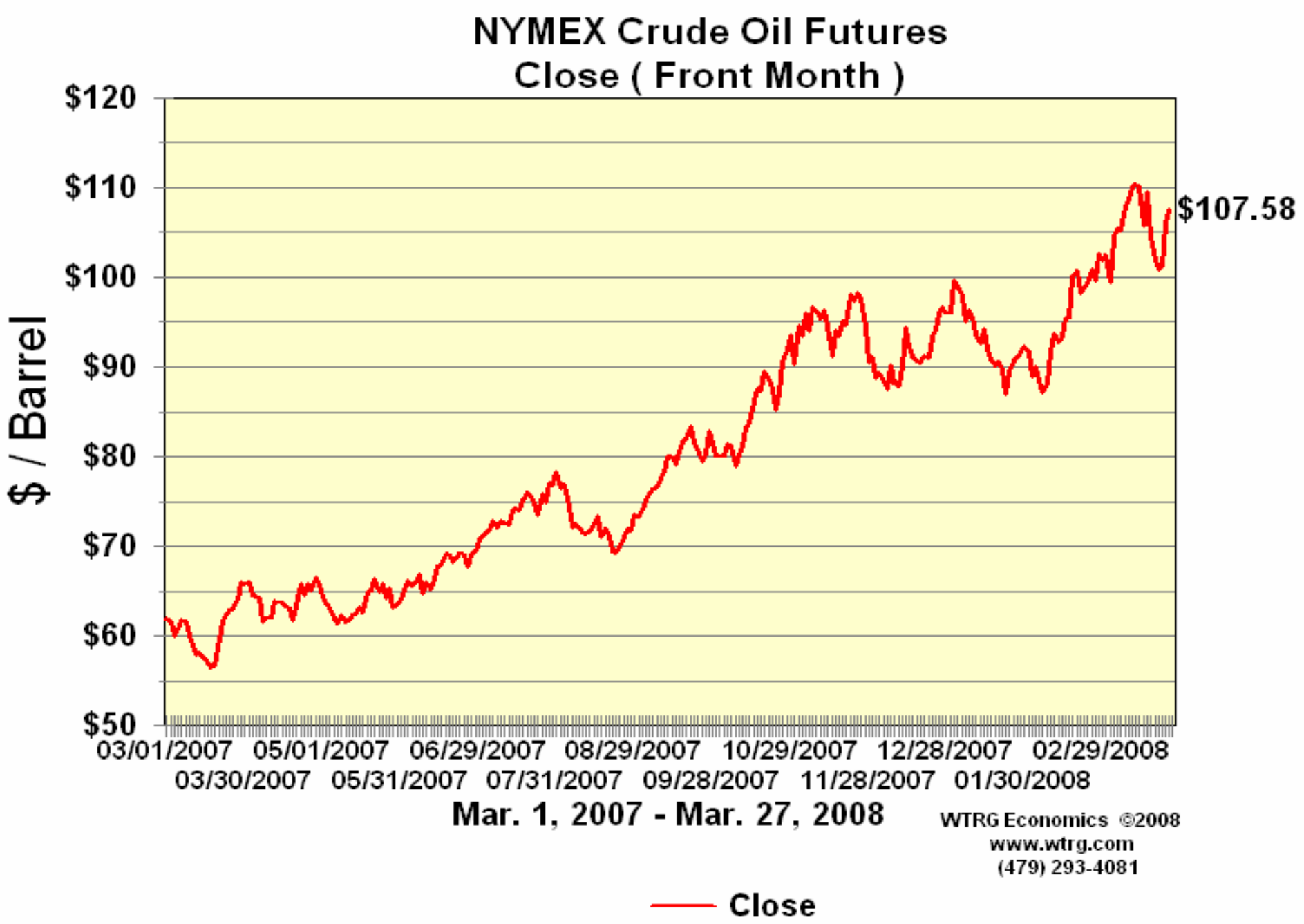
Energy Efficient Buildings

by Jim Cain, OTA

April 15 and 30, 2008

20 Minute Snapshot
Buildings and Energy

- Energy is Becoming Costly
- Building Function and Business Type
- Energy Use Categories
- Environmental Factors
- Useful Literature
- OTA Fact Sheet
- Energy Predictions and Software


NYMEX Crude Oil Futures
Close (Front Month)
$120
$110
$100
$90
$80
$70
$60
$50
$ / Barrel
$107.58
03/01/2007
03/30/2007
05/01/2007
05/31/2007
06/29/2007
07/31/2007
08/29/2007
09/28/2007
10/29/2007
11/28/2007
12/28/2007
01/30/2008
02/29/2008
Mar. 1, 2007 - Mar. 27, 2008
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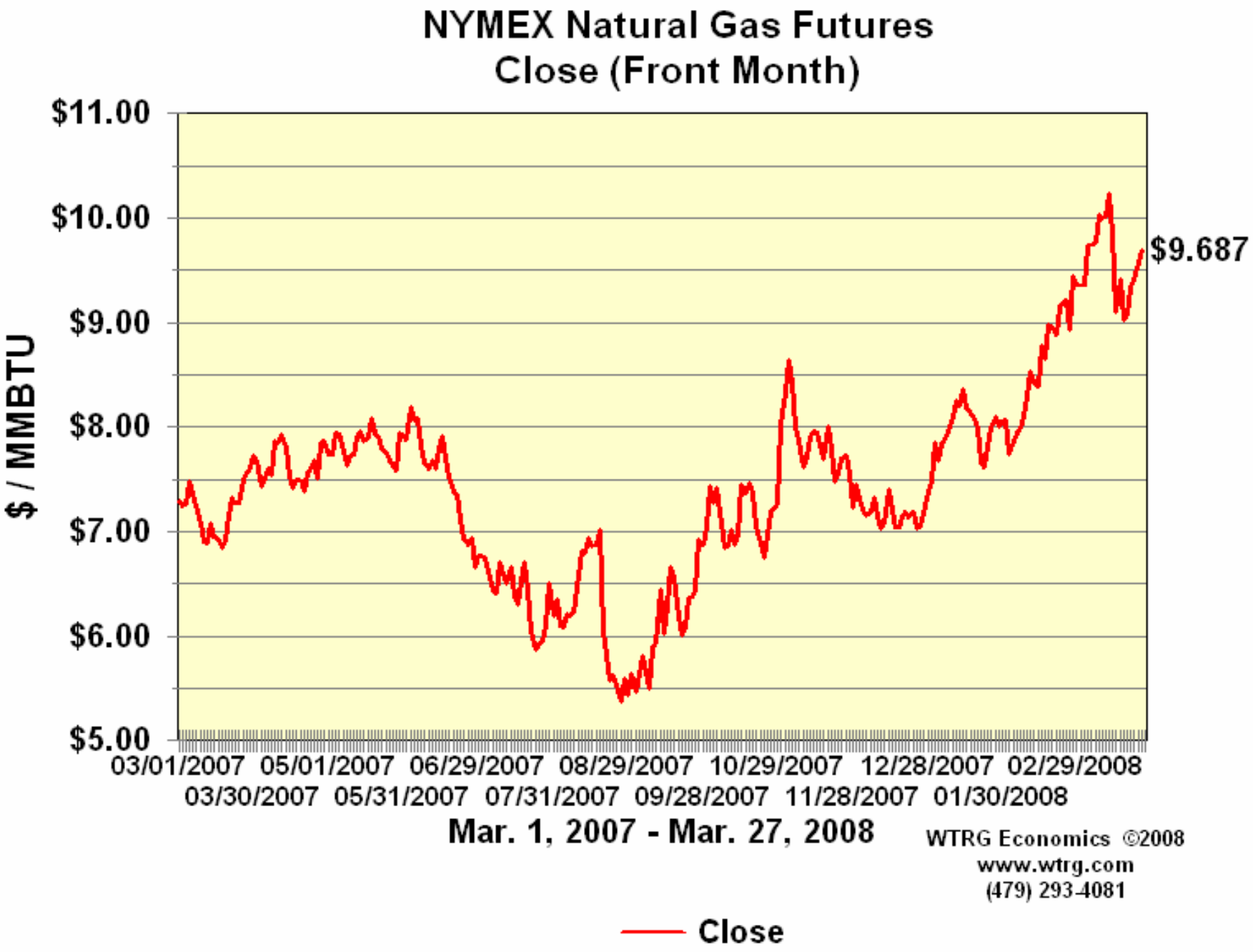
NYMEX Natural Gas Futures
Close (Front Month)
$11.00
$10.00
$9.00
$8.00
$7.00
$6.00
$5.00
$ / MMBTU
$9.687
03/01/2007
03/30/2007
05/01/2007
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06/29/2007
07/31/2007
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01/30/2008
02/29/2008
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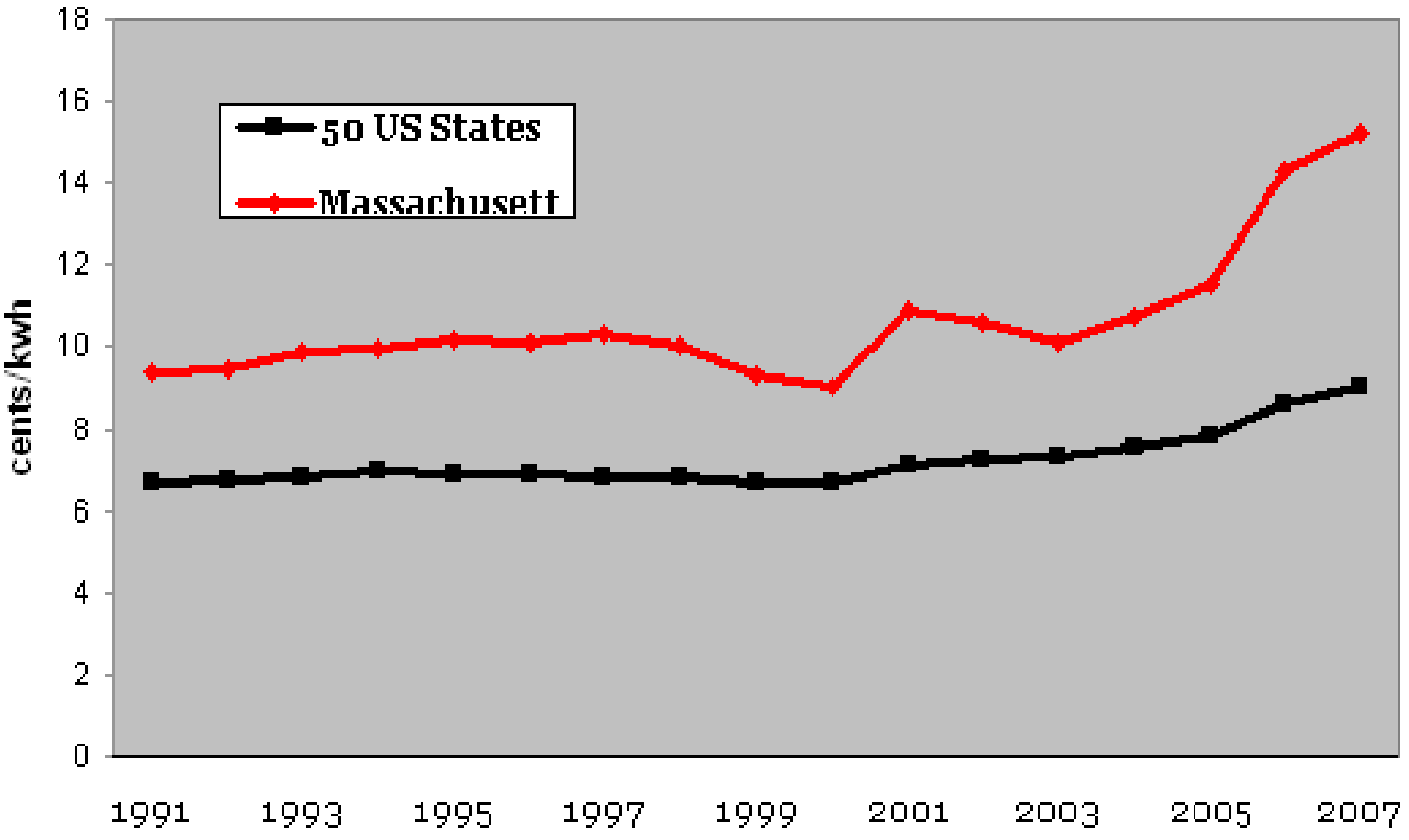
PPI

TOTAL Average Delivered Retail Electricity Price: Massachusetts vs All States



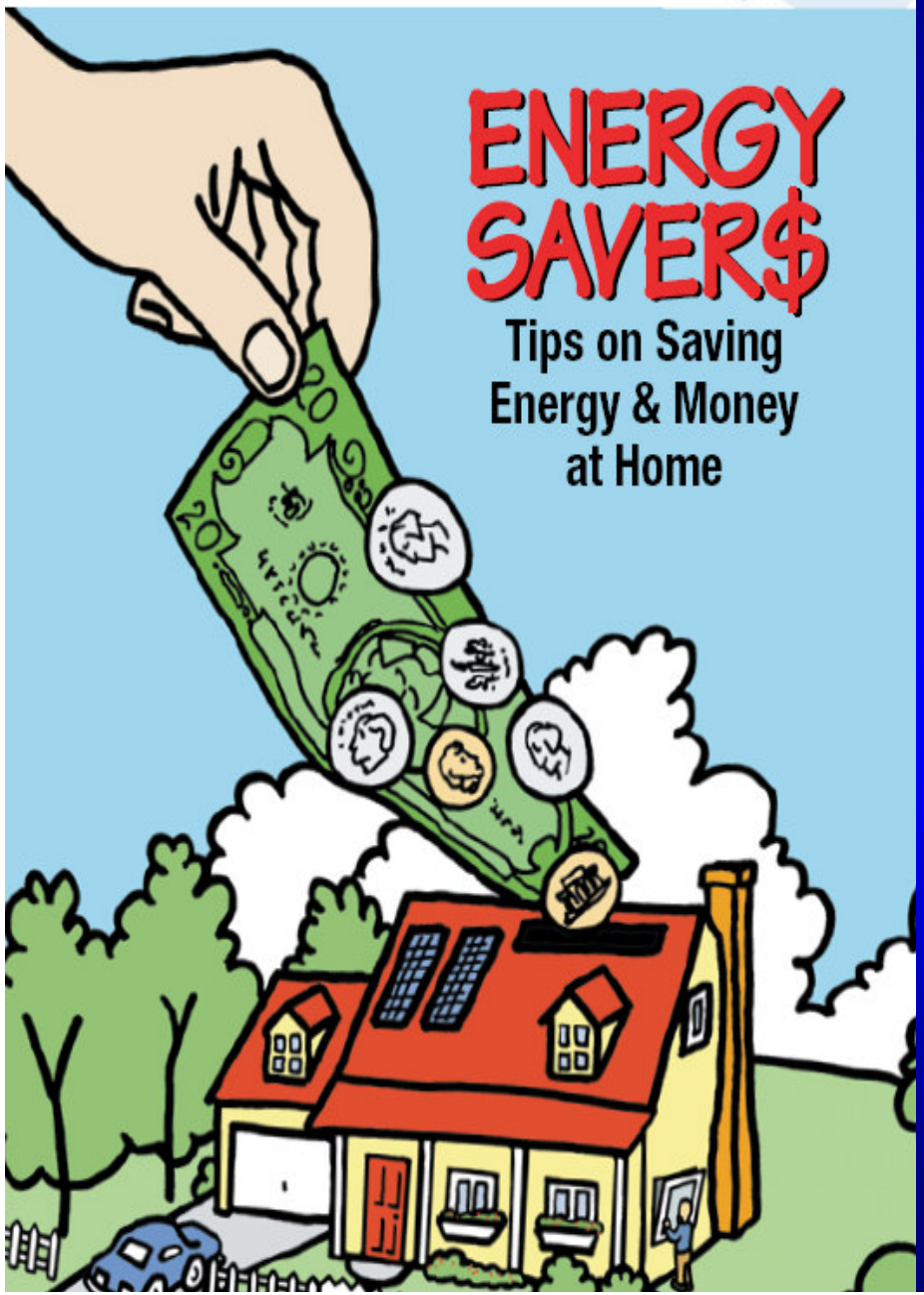
For the 12 months ending in July of each year, through July 2007, EIA Data.

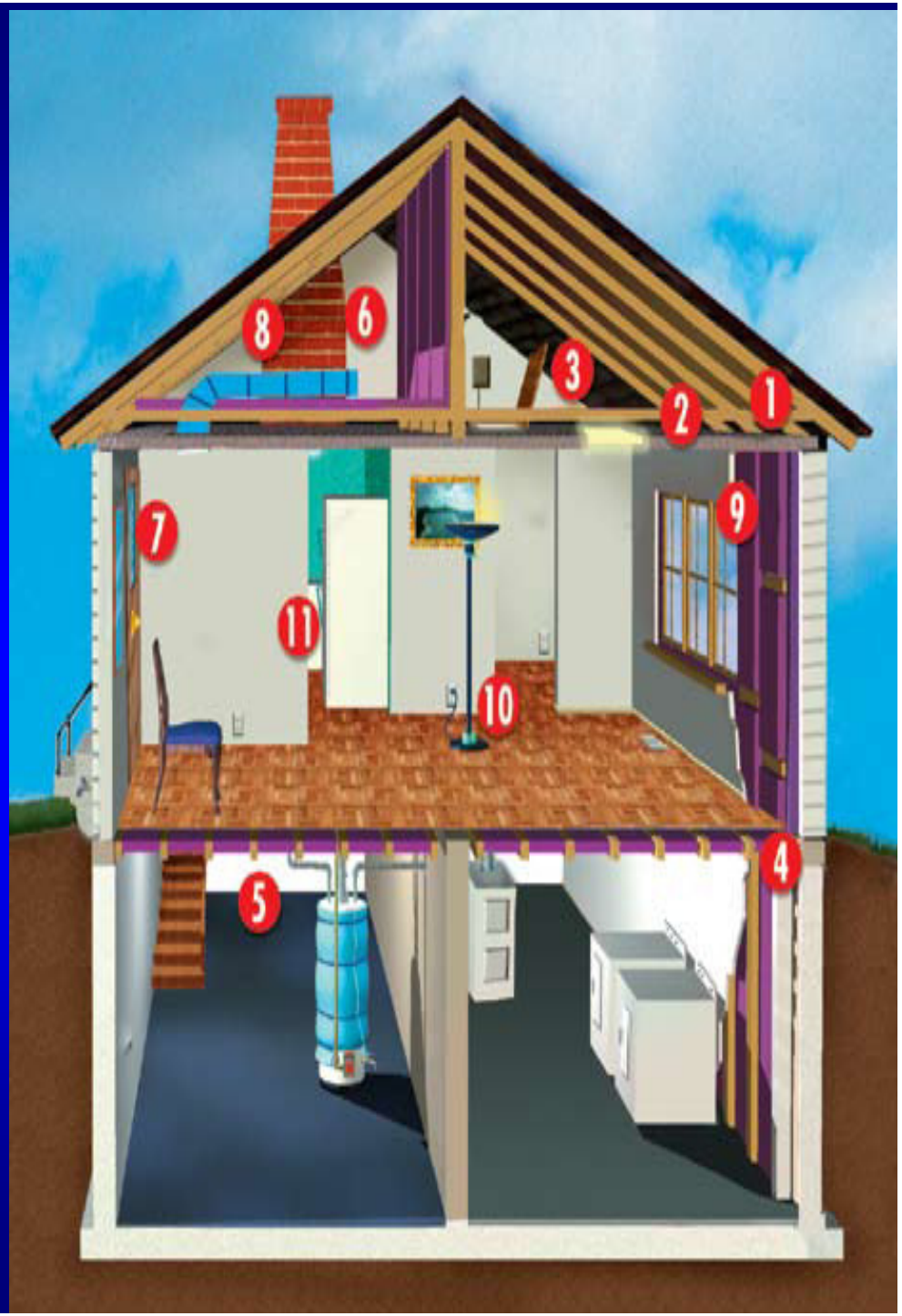
Dec. 2007 Mass. Average = 14.6 cents (all sectors) ; 13.2 cents (industrial)
EIA report 3-13-08

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

ENERGY SAVER$

Tips on Saving Energy & Money at Home





NREL National Renewable Energy Laboratory
A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Innovation for Our Energy Future

Procedure for Measuring and Reporting Commercial Building Energy Performance

D. Barley, M. Deru, S. Pless, and P. Torcellini

Technical Report
NREL/TP-550-38601
October 2005

Form Pack

http://www.nrel.gov/docs/fy06osti/38601_fmpak.doc

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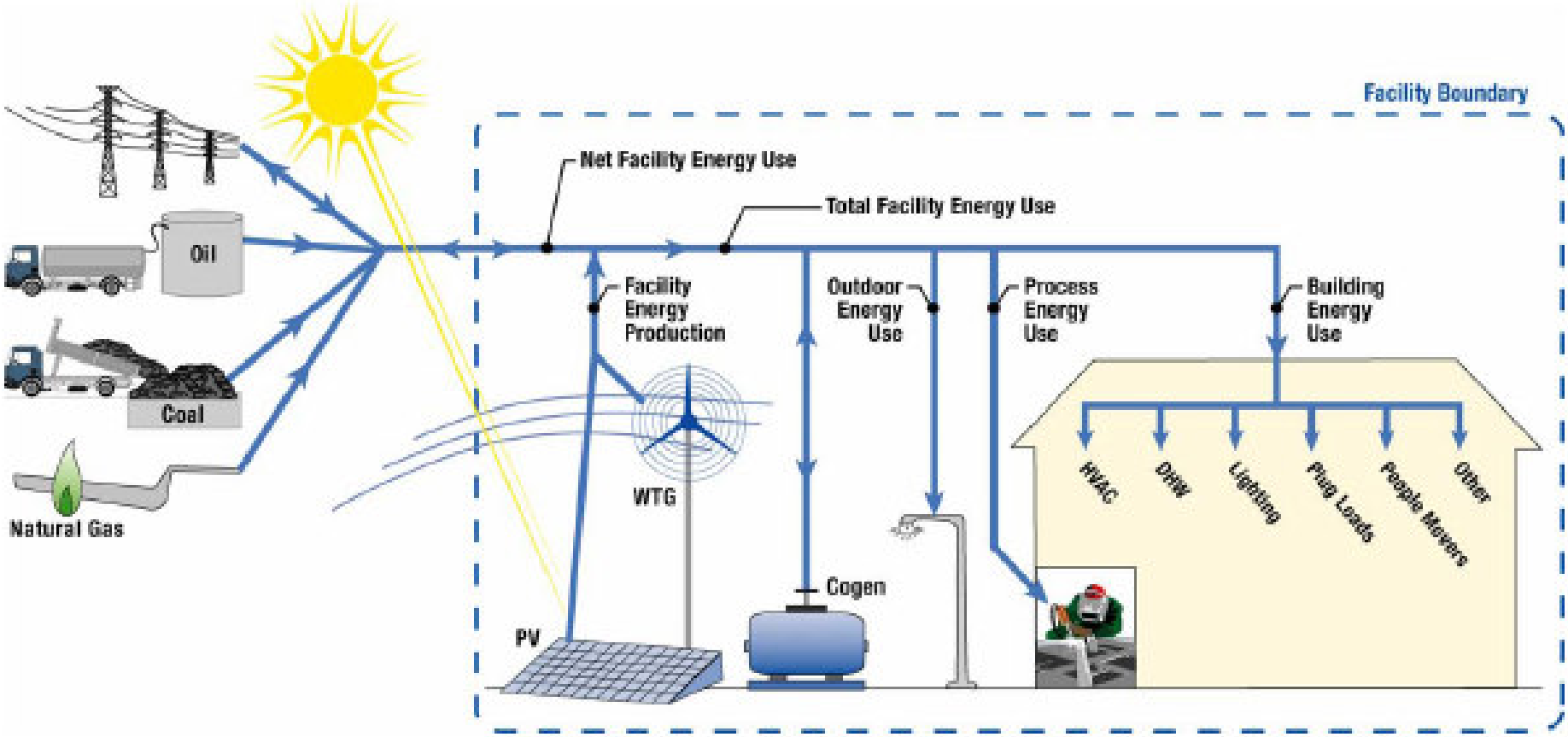
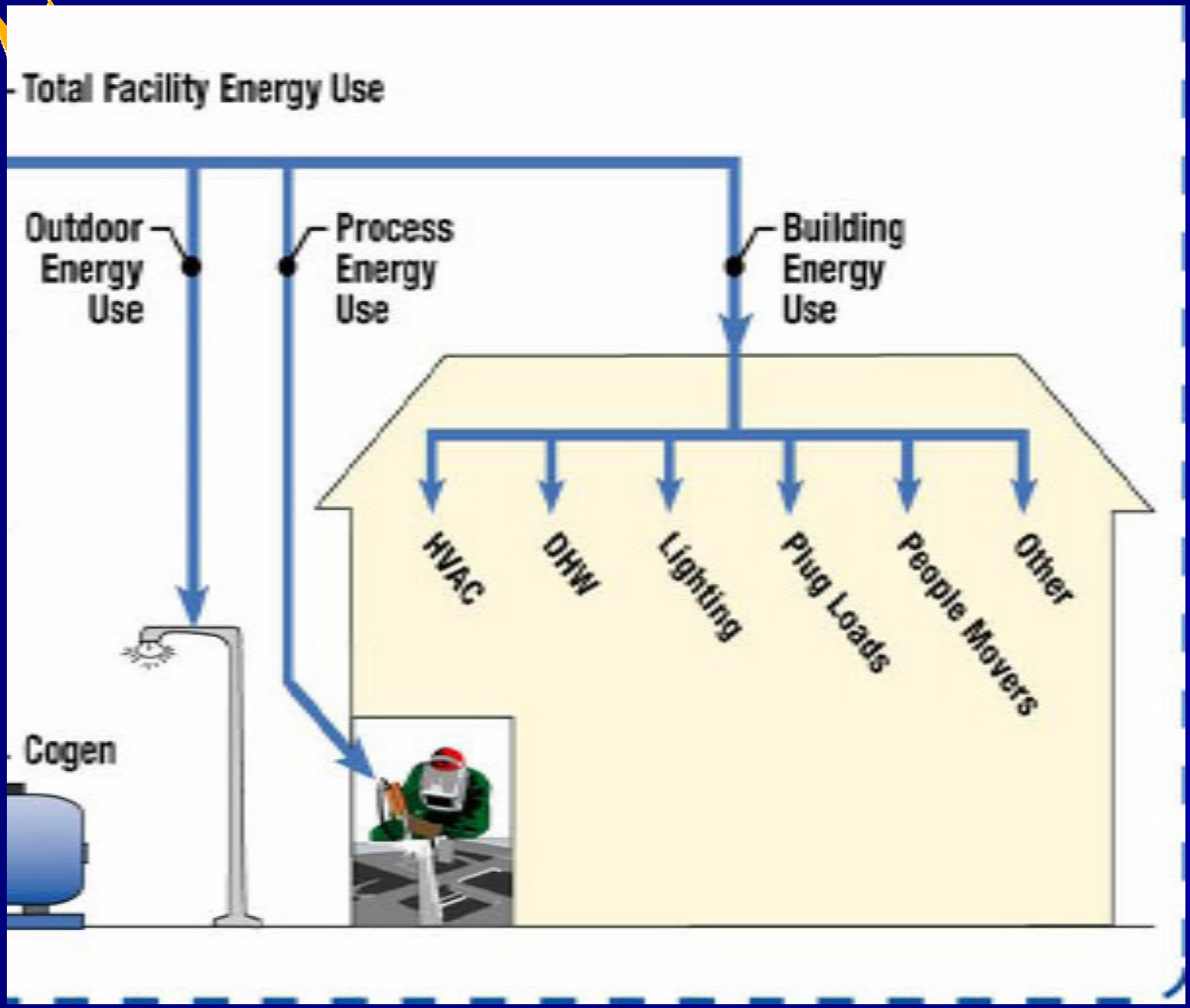


Energy flow diagram providing an overview of this procedure
Figure 4-1 shows a more detailed diagram of the relationships among metrics.

Facility Energy Flow Diagram

(waste heat and emissions not shown)


Total Facility Energy Use
Outdoor Energy Use
Process Energy Use
Building Energy Use
HVAC
DHW
Lighting
Plug Loads
People Movers
Other
Cogen

EIA National Energy Surveys Show Wide Variation in a Facility's Proportionate Use By Business, Function, Region, Site factors, etc

Facility Energy Use	Low	High
Heating: Process and Space	25%	35%
Cooling: Process and Space	2%	7%
Machine Drives and Fans	3%	11%
Lighting	1%	22%
Office Equipment	2%	7%

Massachusetts Office of Technical Assistance and Technology

Energy Conservation Fact Sheet

Energy Saving Tips for Industrial and Commercial Buildings

Introduction

Energy is a significant and growing cost for most businesses. A review of how energy is used in buildings and then targeting improvements in equipment and procedures can lead to big cost savings. Furthermore, many corporate and government programs now strongly encourage energy conservation. The purpose of this fact sheet is to provide useful examples of energy saving tips that relate to the general categories of building energy use, that would apply to most facilities. (Examples of potential savings in direct process uses, which may dominate energy consumption in heavy industry, can be found in the OTA energy efficiency fact sheet).

Facility Energy Use	Low	High
Heating: Process and Space	25%	35%
Cooling: Process and Space	1%	7%
Machine Drives and Fans	3%	11%
Lighting	1%	22%
Office Equipment	1%	7%

Businesses vary greatly in size and purpose, and this will be reflected in the proportionate energy consumption for each category of end use. The accompanying table is derived from national surveys[1] of industrial and commercial facilities. Most Massachusetts manufacturers, with a few exceptions, have energy uses within the ranges of this table. A manufacturer of basic materials would have proportionately more process heating and an assembly facility would have more space heating, lighting, etc. A large facility from heavy industry may have large boilers and even electrical cogeneration while a smaller facility in one of the light industries may have proportionally more energy use for auxiliary food services, domestic hot water, etc.

Devising an energy strategy with the greatest potential savings involves identifying the major energy end uses within the facility. Capital costs and operating costs are also needed for ranking various conservation measures. Note that the payback periods will be affected by hours of operation and load profiles. Avoided peak demand surcharges and other energy pricing variability can be important in planning your energy strategy.

Energy Conservation

Many criteria can be used in decisions whether to install energy-saving equipment or implement new procedures. The most frequently considered are total costs, rate of return, ease of implementation, and certainty of the desired outcome. The following four categories are examples of how your facility can make changes to achieve energy conservation.

HVAC

A big category for light industrial operations is HVAC. Waste heat from processes, lighting, air compressors, etc. can contribute in winter but may not be well distributed. Waste heat at some facilities can create additional cooling loads not only in summer, but to a lesser degree in the other seasons as well.

- Waste heat from compressors can frequently be captured for space heating or other uses.
- Supply air for the compressors and boilers should be from the outside, not indoor air.
- Seal leaks and increase insulation, at least up to recommended R-values.
- Add economizers to the A/C system (a useful technique except on hot, humid days).
- Identify and correct unwanted drafts and unwanted air movement from one area to another.
- Use ceiling fans where appropriate.
- Adjacent rooms that are maintained at different temperatures should be separated by doors or flexible transparent barriers.
- Heating and cooling ducts should be insulated.
- Use automatic controls such as programmable thermostats, time clocks, bypass timers, weather sensors, and activity sensors, where appropriate.
- Areas of building prone to solar heat gain should be shaded in summer and exposed in winter.
- Thermostats should be set cooler in winter and warmer in summer.

Additional Energy Conservation Services

Many electric and gas utilities provide financial assistance for energy audits and energy efficient equipment. Web links to many of these can be found on the OTA Energy Web Page http://www.mass.gov/envir/ota/resources/energyconserv.htm

1. Energy Information Administration: U.S. Department of Energy

Executive Office of Energy and Environmental Affairs
Office of Technical Assistance and Technology

Energy Conservation Fact Sheet

HVAC (Heating, Ventilating, and Air Conditioning)

1. Capture **waste heat**
2. **Supply air** to equipment directly from outside
3. Reduce **infiltration** and increase **insulation**
4. Add **economizers** to A/C system (except when humid)
5. Identify and correct unwanted **drafts** through building
6. Use **ceiling fans** where appropriate
7. Separate / **isolate** adjacent rooms , if at different climates
8. **Insulate** heating and cooling ducts when economical
9. Use automatic and/or programmable **controls**
10. **Shade** east / west windows of building in summer and **expose** south windows (winter
11. Set **thermostats** cooler in winter and warmer in summer

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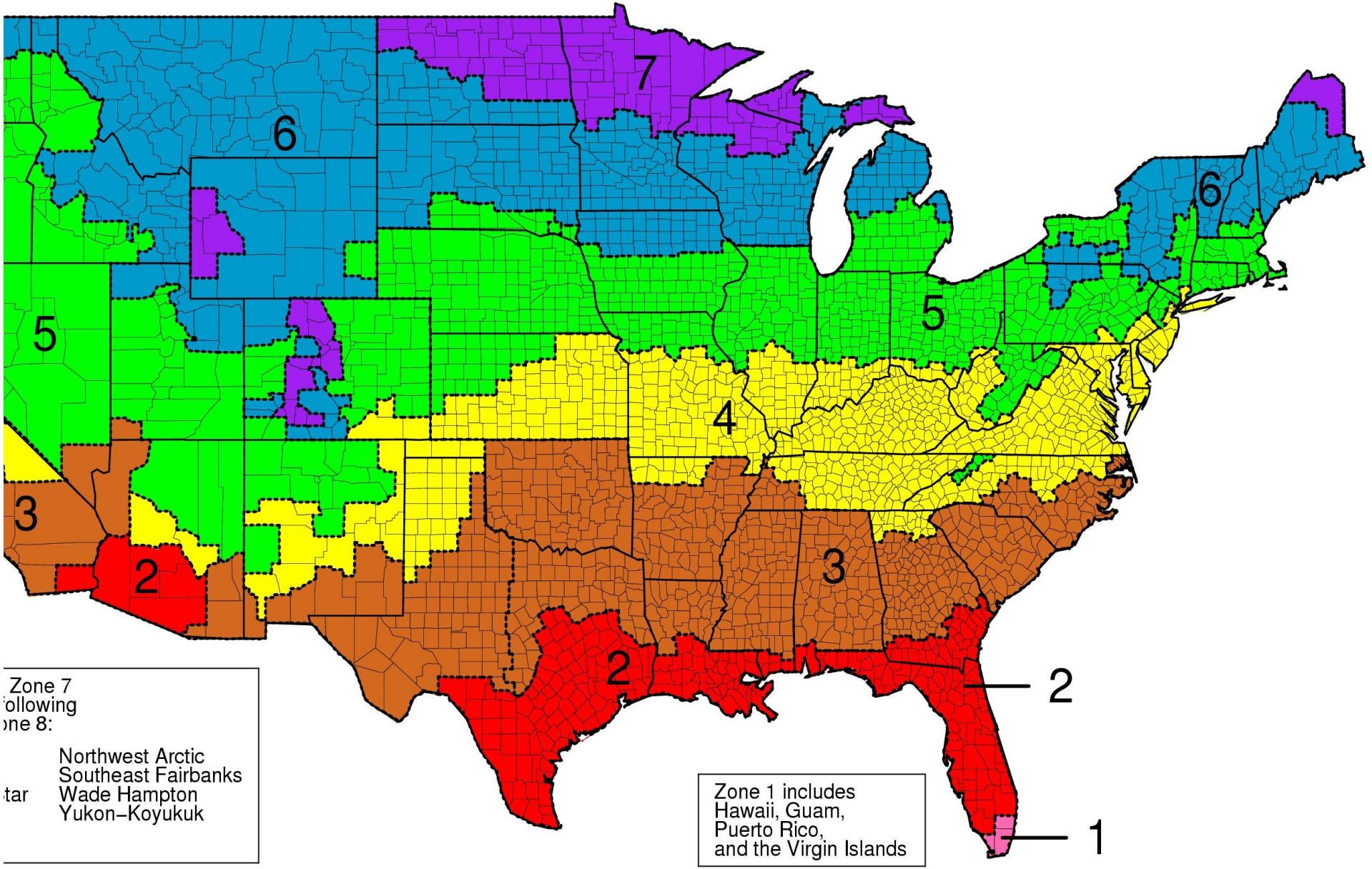
7
6
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3
3
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2
2
1
Zone 7
following
one 8:
Northwest Arctic
Southeast Fairbanks
tar
Wade Hampton
Yukon–Koyukuk
Zone 1 includes
Hawaii, Guam,
Puerto Rico,
and the Virgin Islands

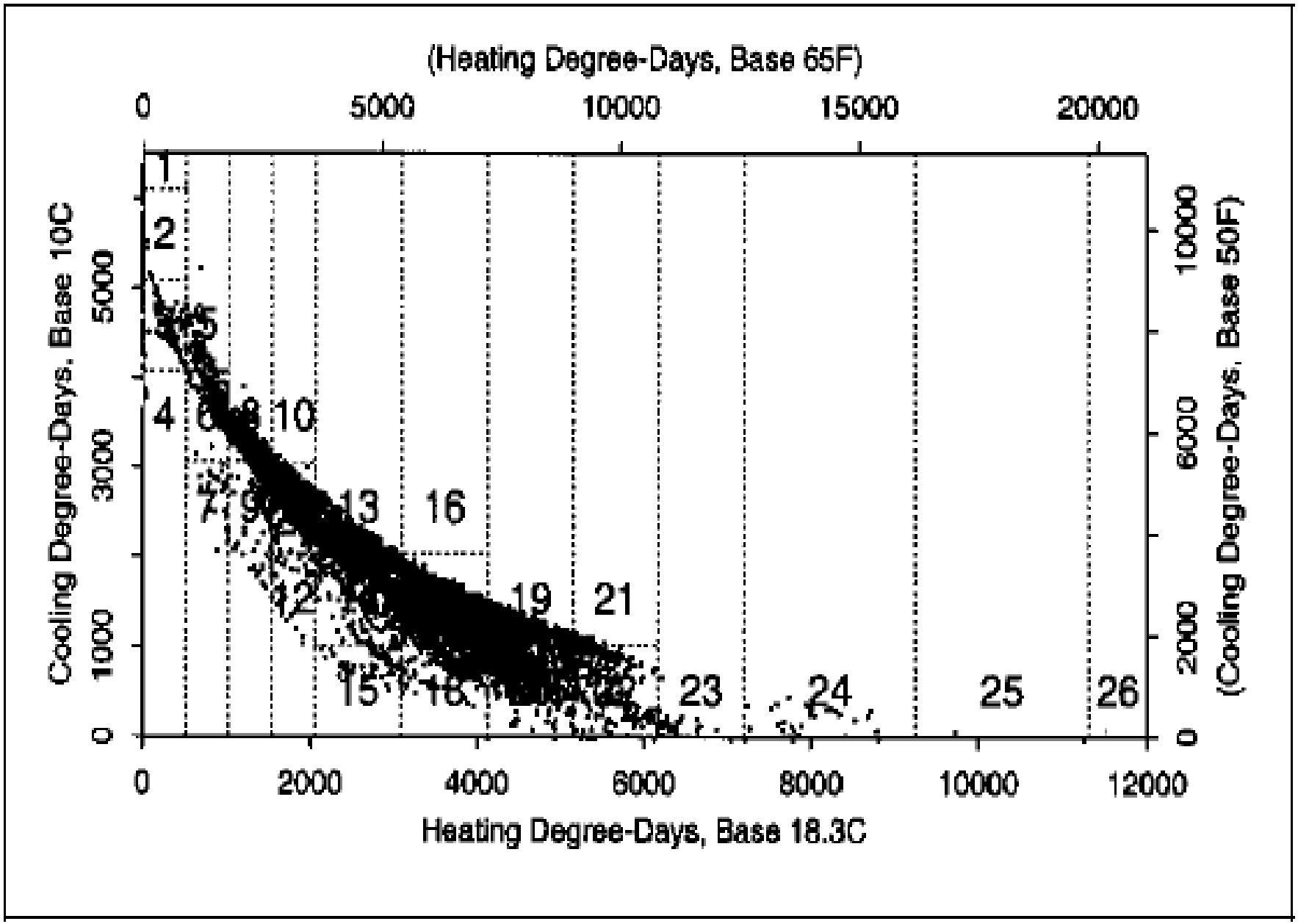
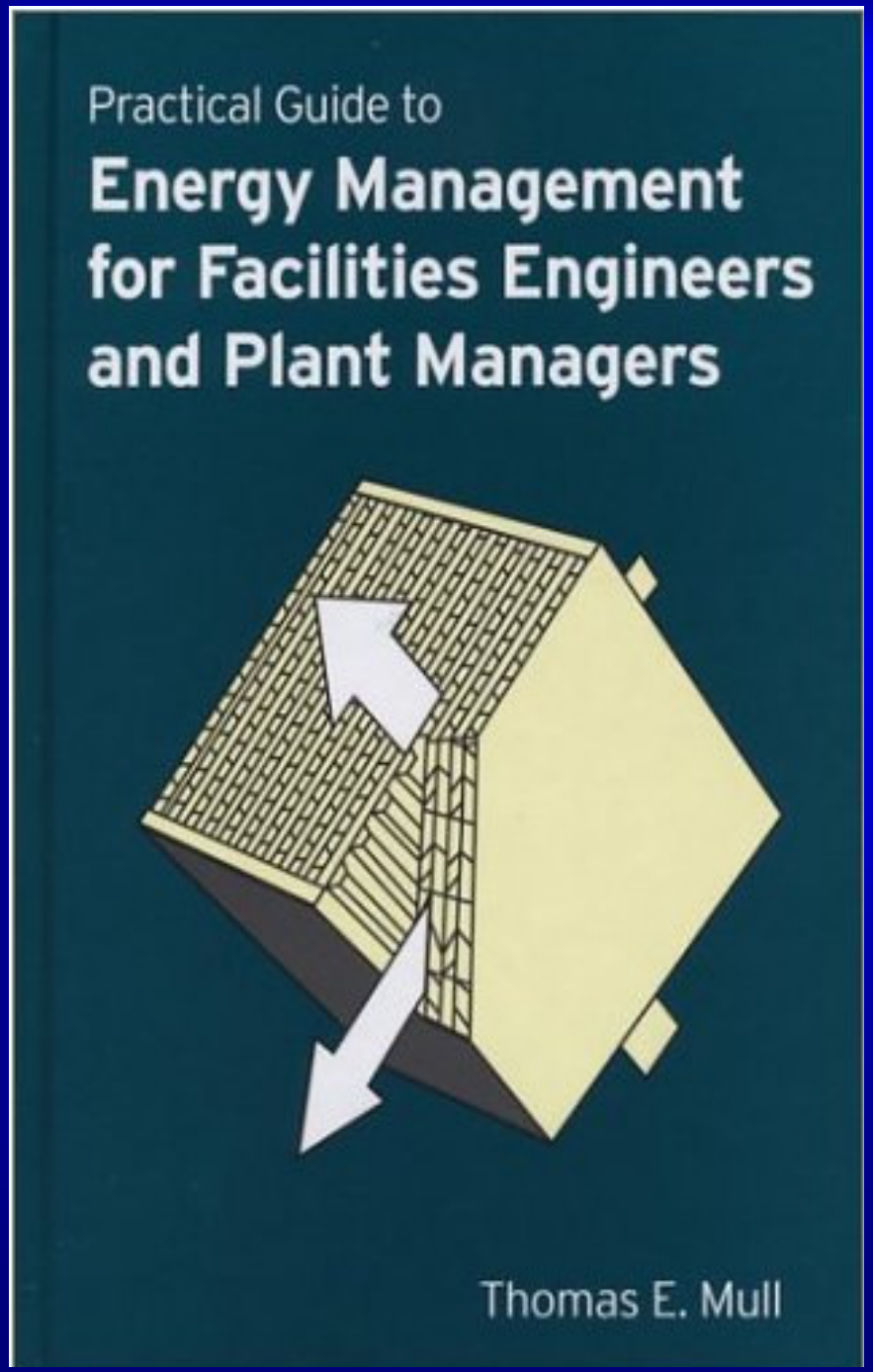


Figure 3 – Distribution of Roughly 5000 U.S. Locations Within 90.1-2001 Climate Bins



600 pages c. 2001 ASME

Introduction to Energy Management
Basic Scientific Principles
Economics for Energy Management
Combustion Systems and Boilers
Steam Systems
Hydronic and Pumping Systems
Chillers and Chilled Water Systems
Cooling Towers and Fluid Coolers
Air Distribution and HVAC Systems
Electrical and Lighting Systems
Compressed Air Systems
Refrigeration Systems
Heat Recovery and Waste Heat Mgt
Thermal Energy Storage Systems
Energy Mgt and Control Systems

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Building Energy: 345 Software Tools

http://www.eere.energy.gov/buildings/tools_directory/

- Whole Building Analysis
  - Energy Simulation
  - Load Calculation
  - Renewable Energy
  - Retrofit Analysis
  - Sustainability / Green Buildings
- Codes & Standards
- Materials, Components, Equipment, & Systems
  - Envelope Systems
  - HVAC Equipment and Systems
  - Lighting Systems
- Other Applications
  - Energy Economics, Atmospheric Pollution, Indoor Air, Training, Ventilation / Airflow, Multibuilding Facilities, Utility Evaluation, Solar/Climate Analysis, Water Conservation, Validation Tools, Misc.

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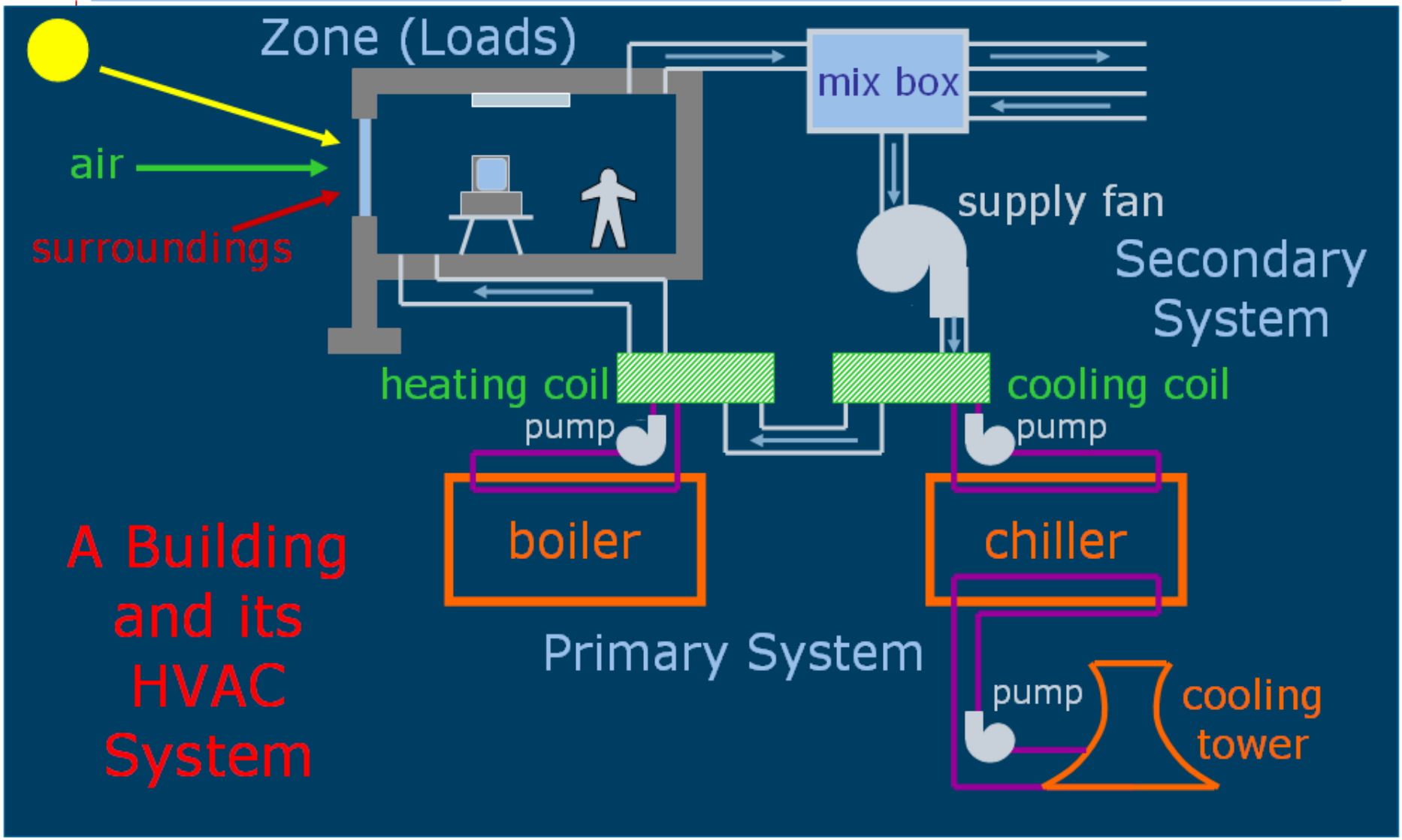
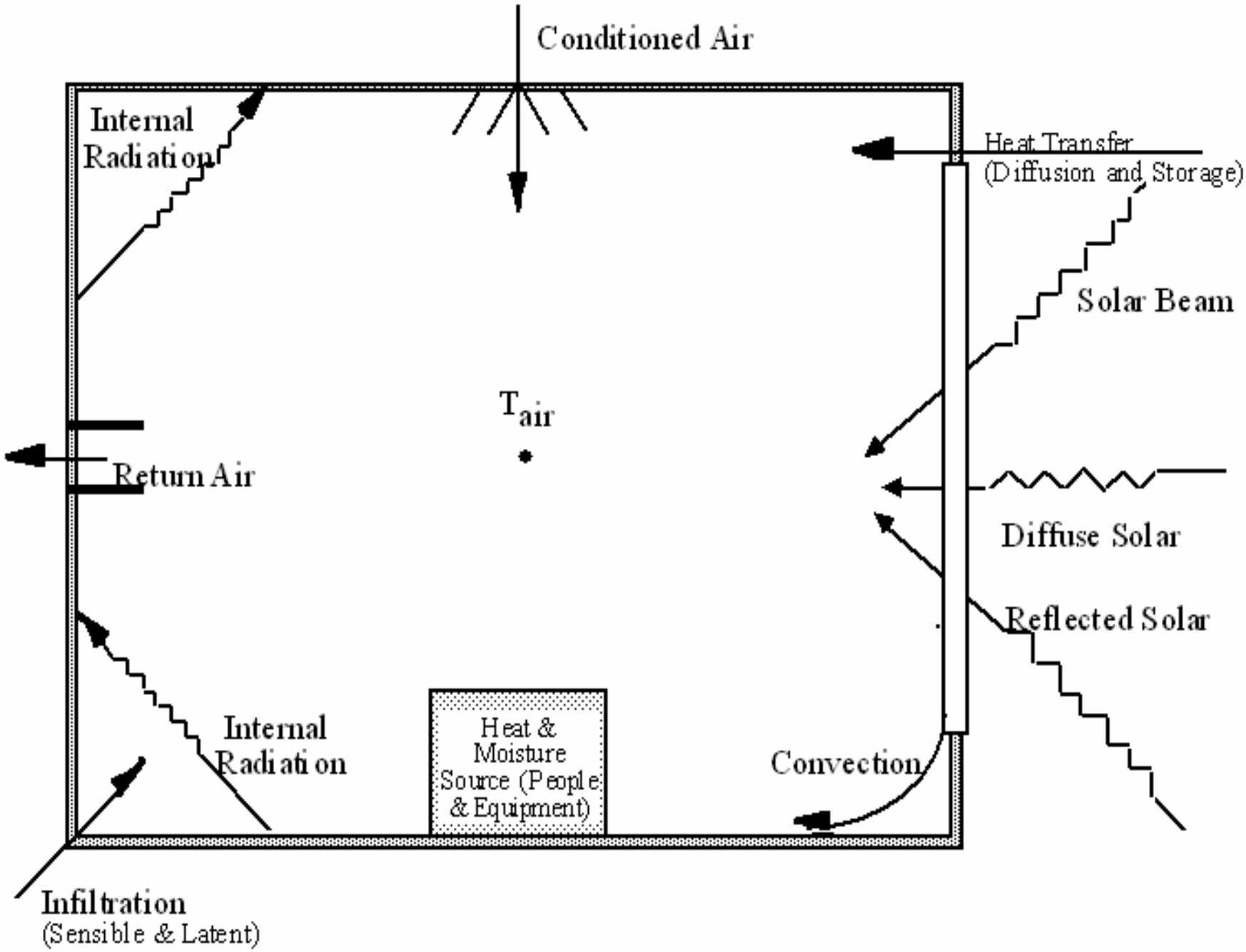
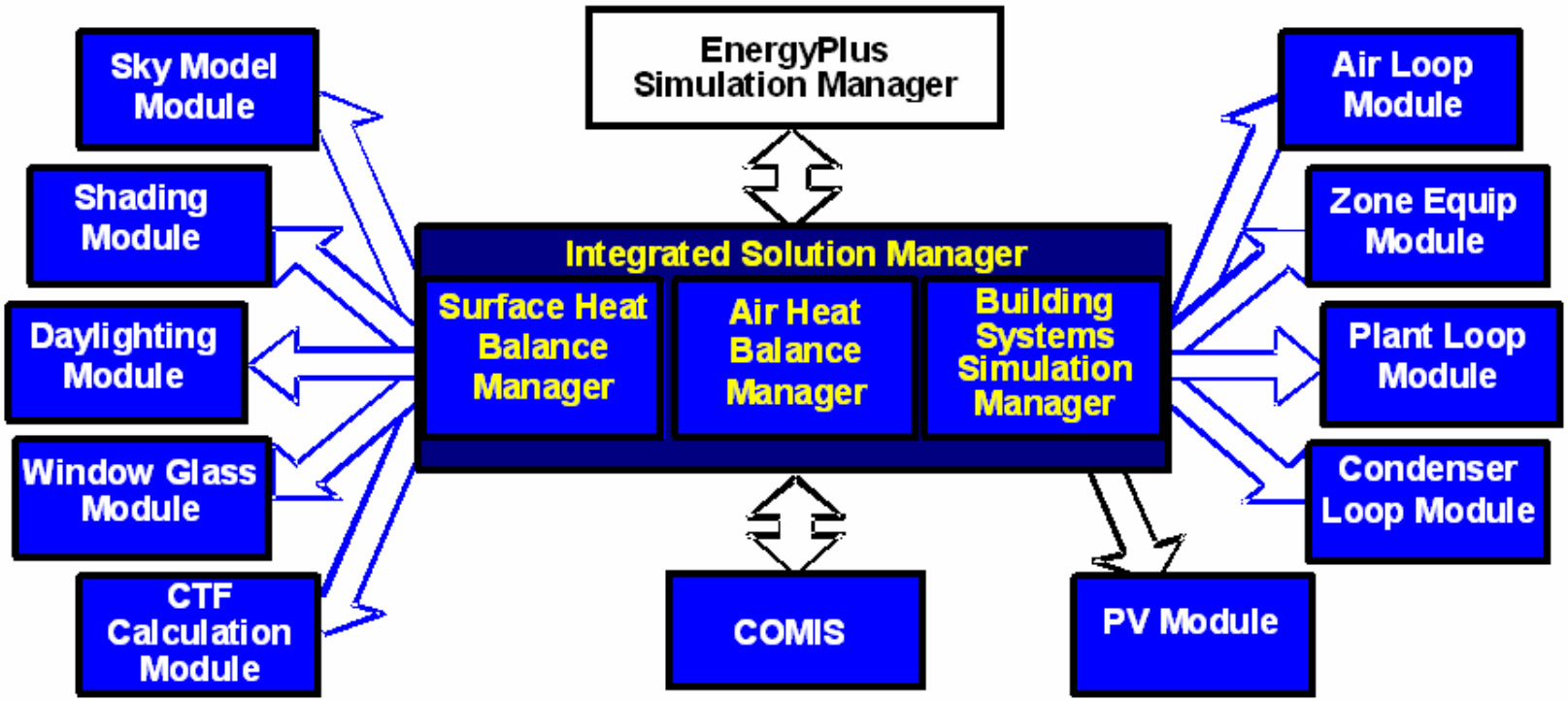
from EnergyPlus Training
by NREL / DOE and
GARD Analytics / Univ of Illinois




Conditioned Air
Internal Radiation
Heat Transfer (Diffusion and Storage)
Solar Beam
T_{air}
Return Air
Diffuse Solar
Reflected Solar
Internal Radiation
Heat & Moisture Source (People & Equipment)
Convection
Infiltration (Sensible & Latent)

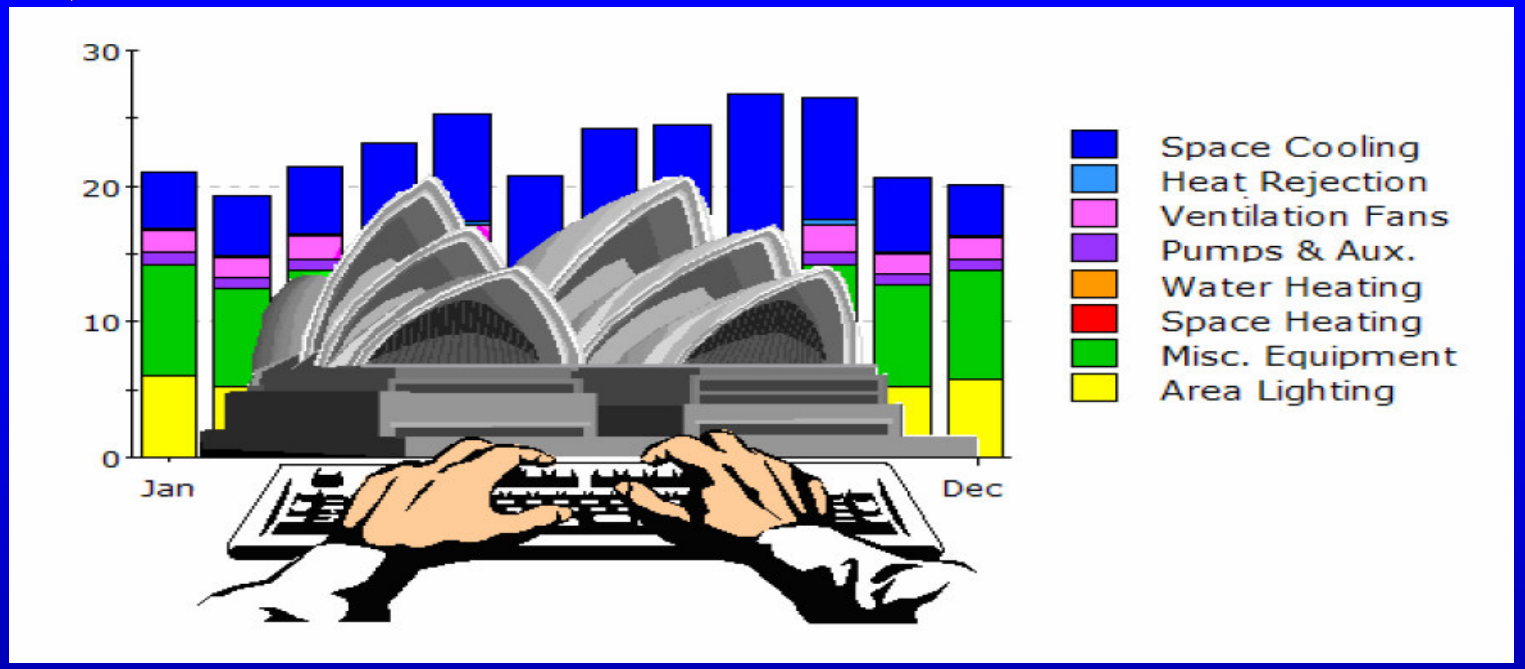
Digital images on this slide courtesy of:
Lisa Fricker, Graduate Student, UIUC

Integrated Simulation Manager (cont'd)



eQUEST from doe.gov

Whole Building Integrated Energy Design



Input: Building Site Info and Weather
Building Shell, Structure, Materials, Shades
Building Operations and Scheduling
Internal Loads
HVAC Equipment and Performance
Utility Rates
Economic Parameters

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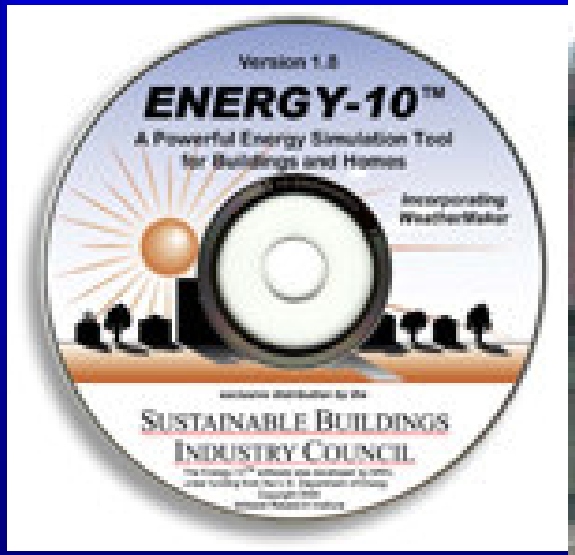
http://www.sbicouncil.org/store/e10.php

- *ENERGY-10™* calculates integrated energy performance and is best suited to buildings with one or two thermal zones. The interface is simple, the analysis thorough, and the results accurate and quick. Building types that are most frequently simulated using this software include retail and office buildings, warehouses, schools, restaurants, residences, lodging facilities, and more.



Verification of Energy-10 Simulations

Thesis by Justin Ng Hsing Aik, NCSU 2005

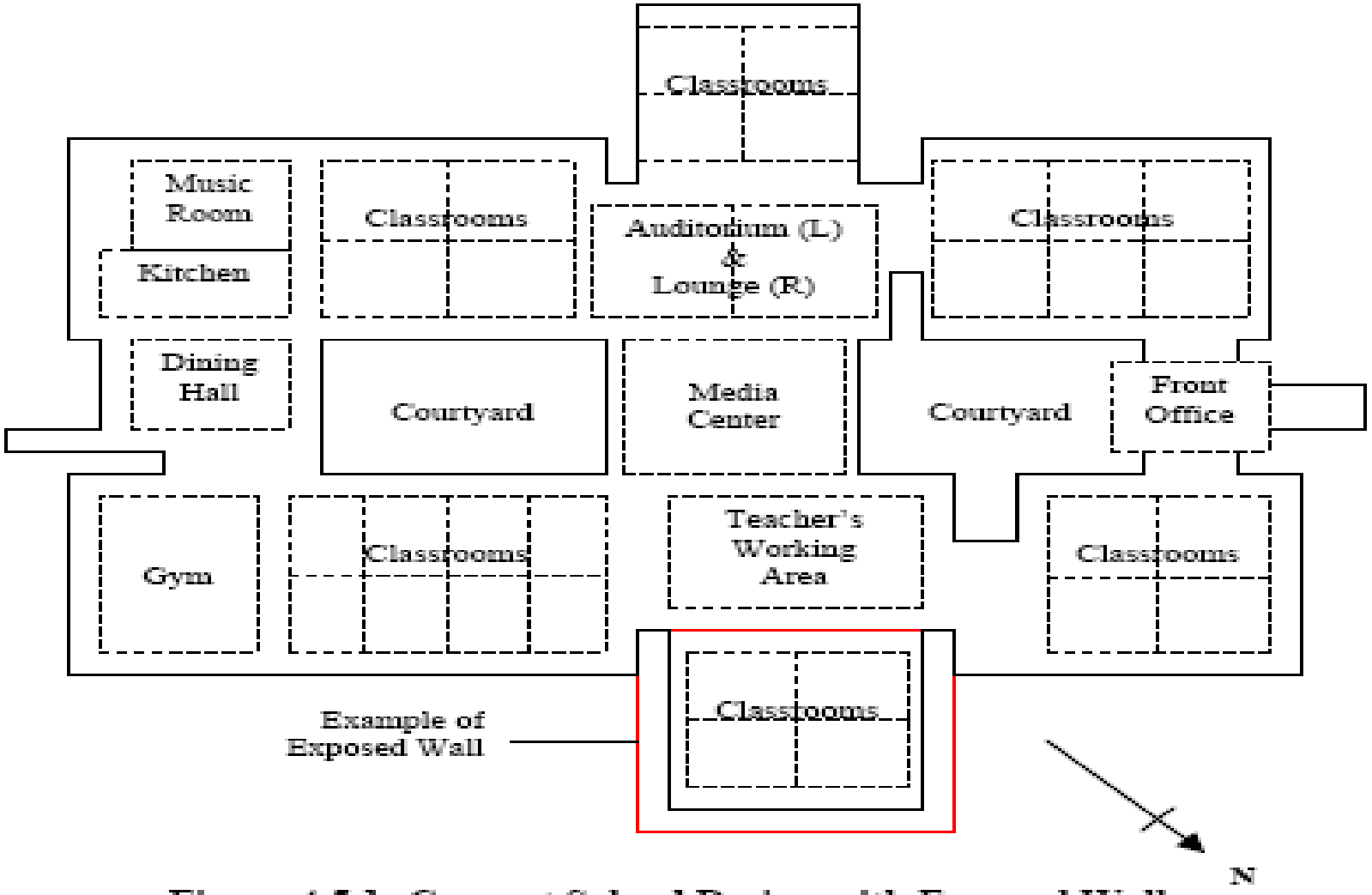


Figure 4.5.1: Current School Design with Exposed Wall

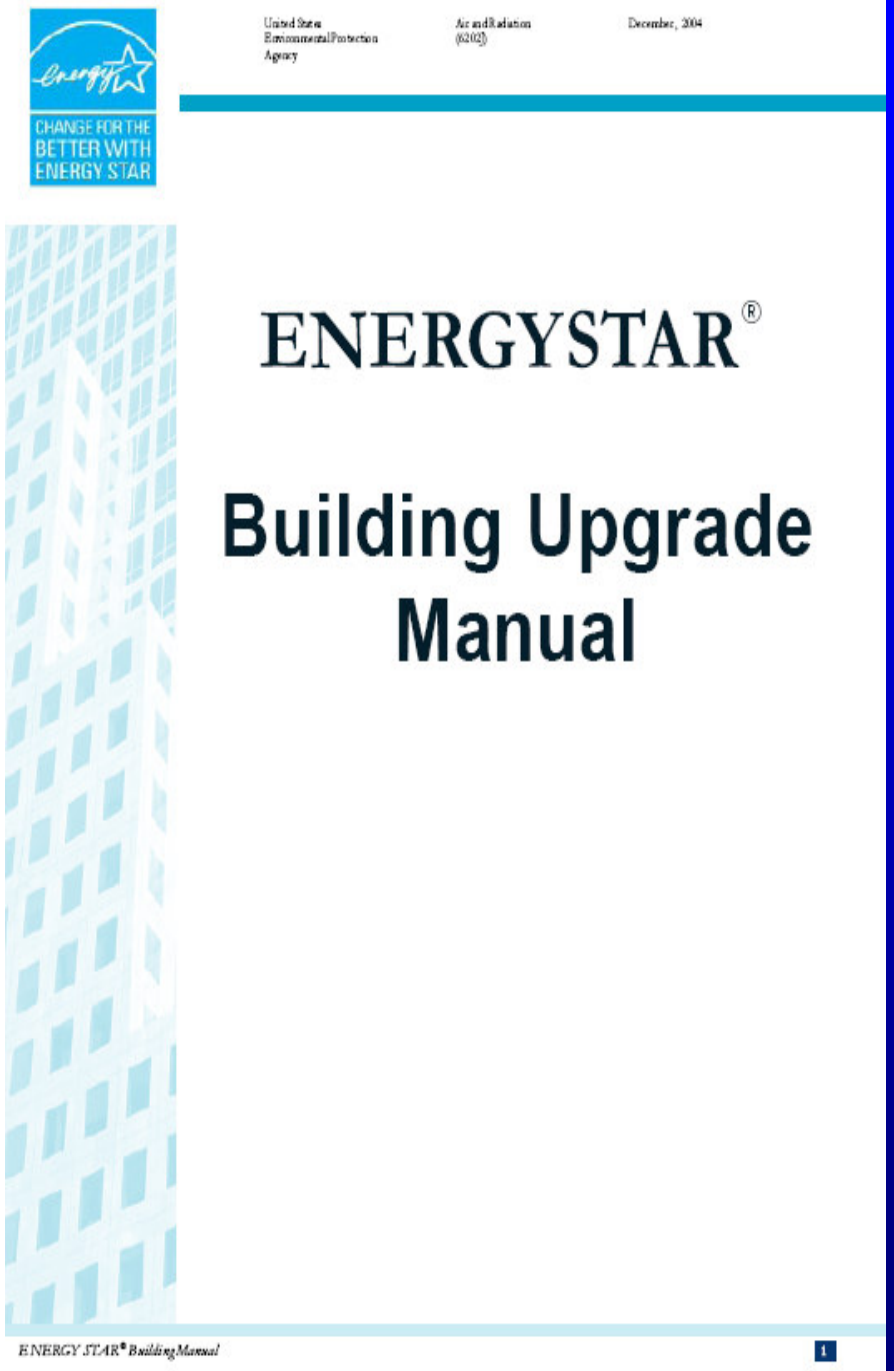
Table 7.0.1: Effects of Various Energy Conservation Measures on Overall School Energy Performance

Energy Conservation Measures	Annual Savings (kWh) / ($)			Implementation Cost	Payback (Months – Unless Noted)	Comments
	For Classrooms 303 and 304	For All 28 Classrooms	For the Entire School			
1. Install high efficiency water source heat pumps	5,669 kWh / $354	79,366 kWh / $4,953	N/A	$97,650 [14]	20 years	Focus of study was primarily on classroom heat pumps. To evaluate all the heat pumps was beyond the scope of this study.
2. Replace T12 fluorescent fixtures with T8 fluorescent fixtures and electronic ballasts	2,178 kWh / $136	30,492 kWh / $1,903	66,792 kWh / $4,168	$9,866	28	These savings represent lighting costs only. An additional 28% can be saved in summer cooling costs.
3. Install an economizer on the heat pump	596 kWh / $37	8,344 kWh / $521	N/A	-	-	Not cost effective.
4. Improved building insulation and envelope sealing	517 kWh / $32	7,238 kWh / $448	N/A	-	-	Not cost effective.
5. Change building design to reduce exterior exposure	451 kWh / $28	6,314 kWh / $394	N/A	-	-	Not cost effective.
6. Utilize temperature setback during the cooling months of April to October	849 kWh / $53	11,886 kWh / $742	27,044 kWh / $1,688	$2,800 [13]	20	This energy conservation measure may be cost effective. Evaluation of other heat pumps is required.
7. Increase ventilation in classrooms to 15 cfm per person (as per ASHRAE Standard 62-2001)	-1,453 kWh / -$91	-20,342 kWh / -$1,269	N/A	Cost prohibitive	An energy loser	Before taking any further action, check the indoor air quality (i.e. check indoor air temperature, relative humidity, CO_2 and CO levels). Consider having an industrial hygienist conduct the first check, before replicating the procedures.

Energy Conservation Measures	Annual Savings (kWh) / ($)			Implementation Cost	Payback (Months – Unless Noted)	Comments
	For Classrooms 303 and 304	For All 28 Classrooms	For the Entire School			
8. Utilize clerestories to provide some daylighting	-32 kWh / -$2	N/A	N/A	-	-	Classrooms 303 and 304 were not oriented to take advantage of daylighting. In general, daylighting is not a technology that can be retrofitted.
9. Eliminate the need for annual carpet cleaning by replacing the existing carpet with alternate flooring	N/A	N/A	95,600 kWh / $5,358	-	-	Carpet cleaning in July requires the school to operate the heat pumps an unusually long period to insure that the carpets are dry and not subject to mold and mildew. In light of increasing energy costs, it is recommended that this drying cost be eliminated by using a different floor covering.
10. Place heat pumps on a timer to eliminate fan and heat pump power during unoccupied periods	6,937 kWh / $433	97,118 kWh / $6,060	N/A	Negligible, since timer is already on-site	Immediate	The savings calculation is based on one mistake per week when the heat pump is left inadvertently operating 24 hours per day.
11. Relocate the computer away from the front of the return air duct	N/A	N/A	N/A	Negligible	Immediate	Placement of the computer in front of the return air duct will affect the volumetric flow rate of the return air, and places an additional load on the heat pump to condition the supply air.

Proposed Measures (School)

- Upgrade Heat Pumps — No
- Install Economizer on Heat Pumps — No
- Upgrade T-12 Fluorescents — Yes
- Insulate Building Envelope — No
- Setback Temp. April-October — Yes
- Timer Fan / Heat Pumps - Winter — Yes
- Increase Ventilation (15 cfm/person) — Req
- Move Computer from Return Air Duct — Yes



(170 pages)
http://www.energystar.gov/index.cfm?c=business.bus_upgrade_manual

Introduction
Business Analysis
Financing
Recommissioning
Tune-up all systems:
- Lighting & Supplemental Loads
- Building Envelope
- Controls
- Testing, Adjusting, Balancing
- Heat Exchange Equipment
- Heating and Cooling System

Lighting
Supplemental Load Reductions
Fan System Upgrades
Heating & Cooling System Upgrades

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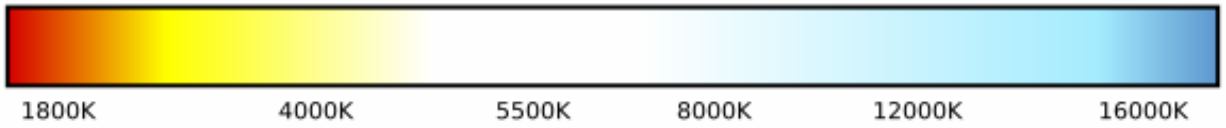


The colors shown are approximate and symbolic, not colorimetrically accurate. A colorimetrically-accurate diagram is available.

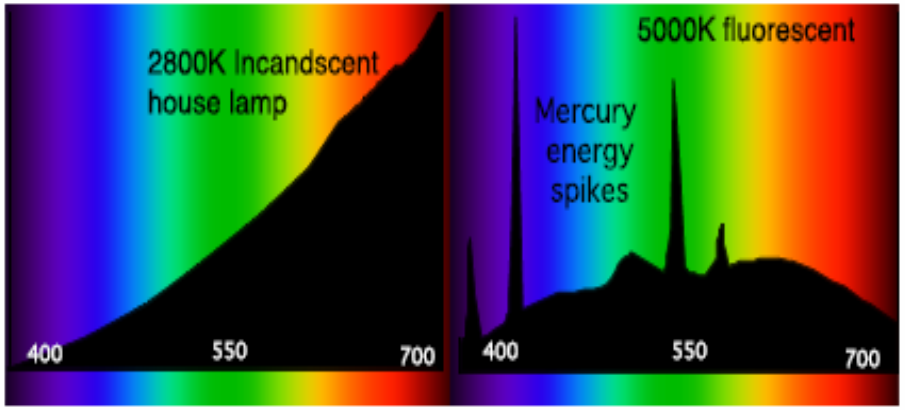
Some common examples.

- 1700 K: Match flame
- 1850 K: Candle
- 2800 K: Tungsten lamp (incandescent lightbulb)
- 3350 K: Studio "CP" light
- 3400 K: Studio lamps, photofloods, etc...
- 4100 K: Moonlight
- 5000 K: Typical warm daylight
- 5500–6000 K: Typical cool daylight, electronic flash (can vary between manufacturers)
- 6420 K: Xenon arc lamp
- 6500 K: Daylight°
- 9300 K: TV screen (analog)

The colors of 5000 K and 6500 K black bodies are close to the colors of the standard illumininants called respectively D50 and D65, which are used in professions working with color reproduction (photographers, publishers, etc.).

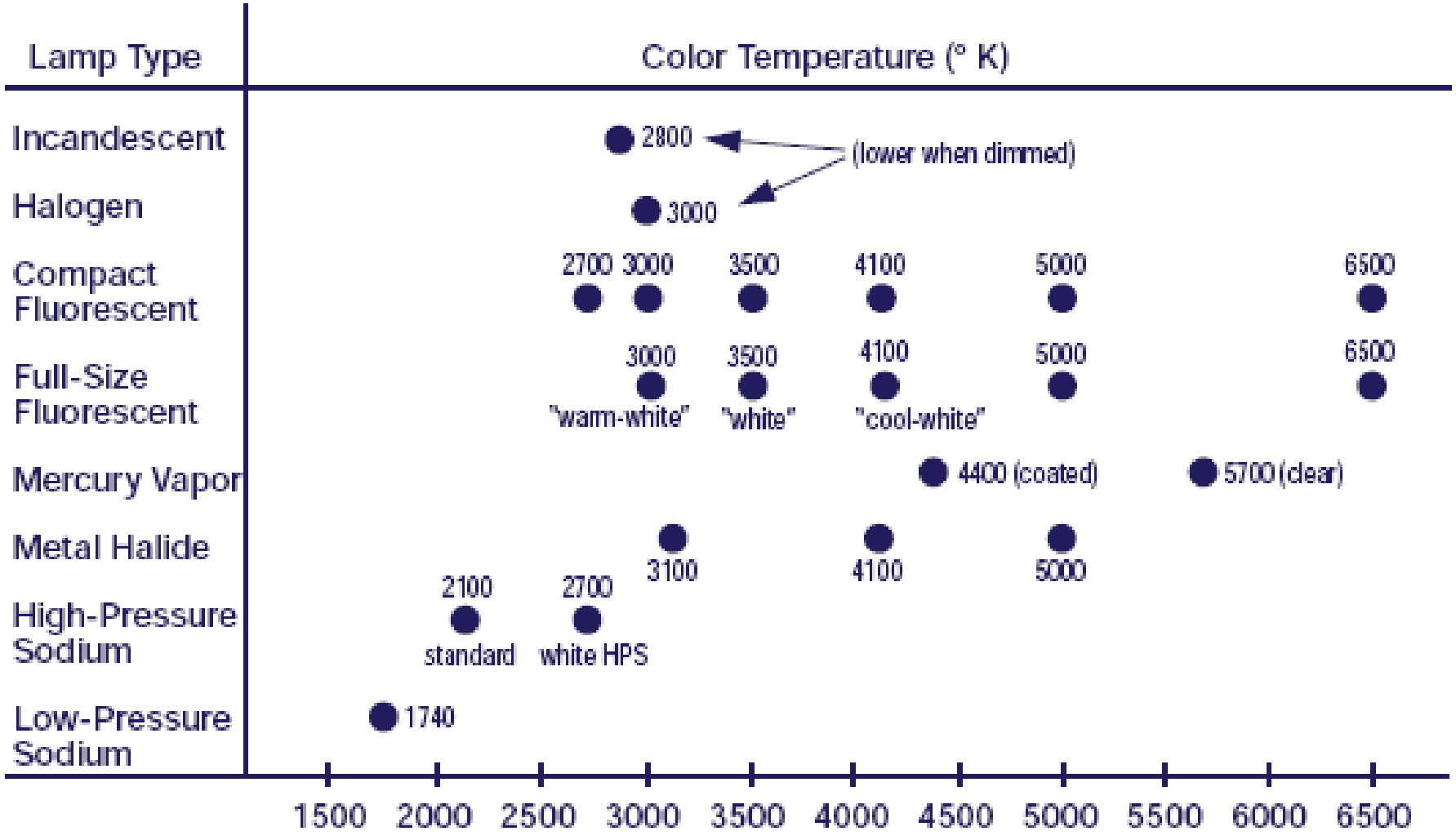
Spectral power distribution plot [edit]

The spectral power distributions provided by many manufacturers may have been produced using 10 nanometre increments or more on their spectroradiometer.[*citation needed*] The result is what would seem to be a smoother (fuller spectrum) power distribution than the lamp actually has. Increments of 2 nm are mandatory[*citation needed*] for taking measurements of fluorescent lights. Here is an example of just how different an incandescent lamp's SPD graphs compared to a fluorescent lamp.



Color Temperature of Various Light Sources

From Energystar Building Upgrade Manual



Lamp Characteristics

From Energystar Building Upgrade Manual

	Standard Incandescent	*Full-Size Fluorescent*	*Mercury Vapor*	*Metal Halide*	*High-Pressure Sodium*
Wattages	3–1,500	4–215	40–1,250	32–2,000	35–1,000
System Efficacy (lm/W)	4–24	49–89	19–43	38–86	22–115
Average Rated Life (hrs)	750–2,000	7,500–24,000	24,000+	6,000–20,000	16,000–24,000
Color Rendering Index	98+	49–85	15–50	65–70	22–85
Life Cycle Cost	High	Low	Moderate	Moderate	Low
Source Optics	Point	Diffuse	Point	Point	Point
Start-to-Full Brightness	Immediate	0–5 Seconds	3–9 Minutes	3–5 Minutes	3–4 Minutes
Restrike Time	Immediate	Immediate	10–20 Minutes	4–20 Minutes	1 Minute
Lumen Maintenance	Good/ Excellent	Fair/ Excellent	Poor/Fair	Good	Good/ Excellent

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ENERGY STAR® Guide for Small Business

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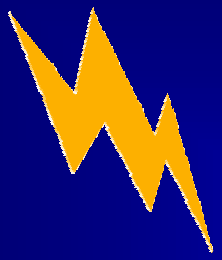

Donald R. Wulfinghoff

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Chiller Plant	12 topics	200 pages
Service Water Systems	3 topics	100 pages
Air Handling Systems,	9 topics	200 pages
Room Conditioning Units & Self-Contained HVAC Equipment -		100 pages
Building Air Leakage -		70 pages
Building Insulation -		30 pages
Control and Use of Sunlight -		100 pages
Artificial Lighting -		150 pages
Independent Energy-Using Components –		40 pages
Reference Notes -		160 pages

Energy Mgt Tools
Energy Sources
Mechanical Equipment
Building Envelope
Lighting

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How Can OTA Help You ?

Jim Cain, environmental Engineer

James.Cain@state.ma.us

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www.mass.gov/envir/ota